Deep active modeling for Physics

Keywords: Machine learning, active learning (Design of Experiment), complex physical systems, deep neural networks, dynamical systems.

This internship is part of a larger project dedicated to building a bridge between Machine Learning and Dynamical Systems: inferring models more robust and less data hungry thanks to physics-based constraints, inspecting the behavior of the models, providing some online guarantees, and relating Physics and computational regularities to improve the model understanding and assessment. Specifically, Machine Learning-based (surrogate) modeling is thoroughly revisited in view of the constraints complex Physics systems are supposed to obey. These constraints are usually derived from Physics first principles (invariant quantities, symmetries, bounds, asymptotic behavior, stability, etc). The connection between Physics and Machine Learning is nowadays considered in both directions and the scientific construction of this domain is underway.

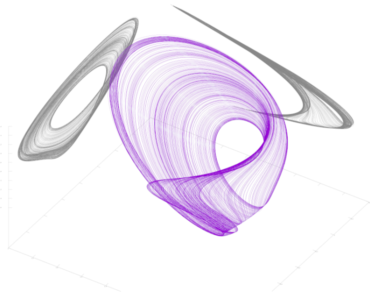

Figure 1: 2-D projections of the Lorenz 9-D attractor.

The internship will focus on an active approach to learning a model for a Physics-driven system:

1. A carefully designed dataset, tailored to the particular objective at hand, has a dramatic impact upon the quality of the resulting model it allows to derive. The student will be involved in assessing the potential of information criteria to qualify the relevance of the training set, and to implement and develop an adaptive Design of Experiment strategy (aDoE).

2. Adapting the dataset should go together with finding a good structure for the model. He/she will focus on deriving refinement criteria of the structure based on the functional gradients and will leverage on an adjoint-based a posteriori refinement framework.

Student profile

The candidate should have a solid background in statistics, machine learning and/or applied maths; knowledge in Python language is preferred. Datasets are already available and tools will be provided for the numerical simulations of physical systems (e.g., high-dimensional Lorenz attractor as illustrated in Figure 1).

Research environment

The internship will be carried out remotely or on the site, at LIMSI-CNRS[1] (`www.limsi.fr`) on the campus of Université Paris-Saclay, depending on the evolution of the Covid-19 pandemics. Frequent interactions are expected with collaborators at LRI-INRIA, (`www.lri.fr`). The partnership is already actively collaborating at the crossing between machine learning and Physics, with a focus on fluid mechanics.

- Advisors: L. Mathelin (`mathelin@limsi.fr`) and O. Semeraro (`semeraro@limsi.fr`) at LIMSI-CNRS; M. A. Bucci (`michele-alessandro.bucci@inria.fr`) at LRI-INRIA.

- The scholarship amount is about 3000 euros, funded by ANR. The internship is 5-month long and ideally starting in March/April 2021. PhD positions are also available starting in September/October 2021.

[1]Note that starting January 2021, the `LIMSI` and `LRI` laboratories will merge in `LISN`.